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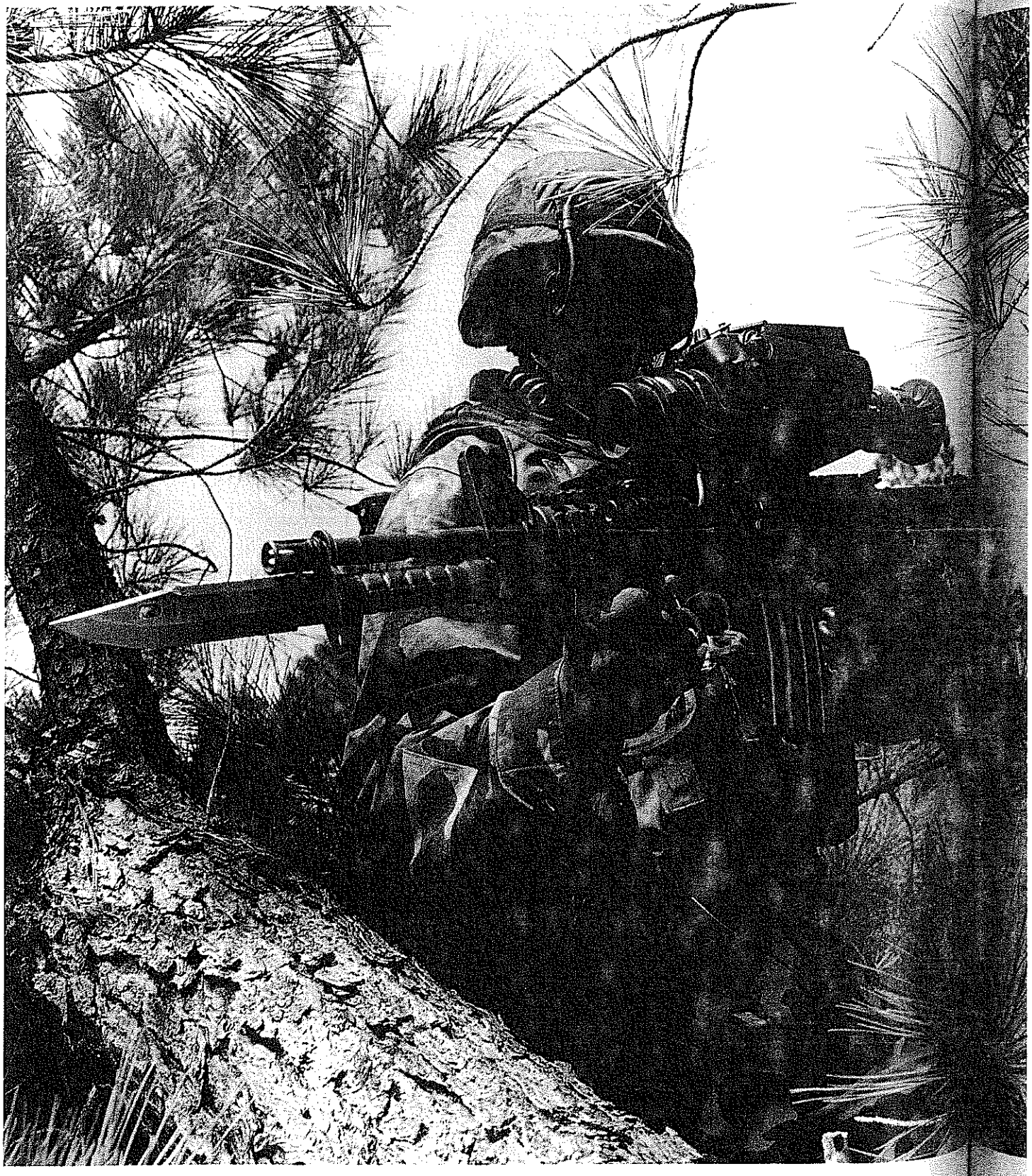

Science for the Soldier: The U.S. Army's Natick Labs

by Philip Brandler

In conducting state-of-the-art research in the basic and applied sciences, the U.S. Army Natick Research, Development and Engineering Center is taking its mandate of protecting and sustaining the individual soldier into the new millennium.

U.S. Army SSCOM Photo

Throughout its nearly 50-year history, the U.S. Army Natick Research, Development and Engineering Center has followed a simple mandate: to ensure that American soldiers are the best fed, best protected, and most highly mobile in the world. From its World War II roots as a facility of the Quartermaster Corps to its present-day status as a premier research and development organization, the Natick center has consistently embraced the principle that sustaining and protecting the individual soldier with ever more sophisticated technology will lead to a stronger national defense and a safer nation. Today, as a recognized leader in the food, textile, aerodynamics, and engineering sciences, Natick is home to ideas, technologies, and products that have been shaping both the U.S. military forces and the broader world for decades and that will continue to do so well into the 21st century.

In conducting both basic and applied research, Natick's scientists, engineers, and equipment designers provide the army and other branches of the U.S. military with a wide range of field-feeding and life-support systems, clothing, precision airdrop equipment, and protective gear against ballistic, chemical, and laser weapons. Basic research into textile materials, for example, has led to the creation of new fabrics that are lighter in weight, more durable, and more weather-resistant than anything soldiers have ever worn. Research into polymeric composites has resulted in helmets that are stronger, lighter, and more protective than the steel "pots" used in World War II and the Korean and Vietnam wars. Investigation of the nutritional requirements of the human body has led to a new understanding of how to sustain a soldier's peak performance under stress with rations that contain the optimum mix of ingredients and are easy to prepare in remote locations.

In addition to its role in crafting the soldier of the future, Natick has pioneered ways of reaching out to the

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EB Inc.

The extreme environmental conditions encountered in World War II sent the U.S. Army a sobering message that the equipment it had designed for its soldiers was clearly inadequate and that changes were imperative.

nonmilitary community. Through cooperative agreements with other government agencies and private industry, it has developed much of the food eaten by space shuttle astronauts during their missions; outfitted police forces with special ballistic protection against bullets, shrapnel, and other flying objects; and developed shelf-stable sandwich foods that promise to combine convenience and nutrition for a consumer market.

EARLY YEARS

Ground was broken in 1952 on a 32-hectare (78-acre) site in Natick, Massachusetts, for what was then called the Quartermaster Research Laboratory. In actuality, however, the facility can trace its origins back another decade, to the early years of World War II. That war delivered a stark message to the U.S. Army that the equipment it had designed following World War I was decidedly inadequate for the extreme climatic conditions that American forces were encountering in such places as the jungles of the southwest Pacific and the sands of northern Africa. As reports came in of tents falling

victim to mildew in the Pacific, of troops being immobilized by trench foot in the Aleutians, and of food being pitched into the sea after commercial packaging techniques had failed to keep it wholesome, it became apparent to army leaders that changes needed to be made.

The office of the Quartermaster General established a Research and Development Branch in 1942 to augment existing army material with equipment that would serve the soldier in any environment in the world. The new branch was headed by Col. Georges Doriot, a French-born American who would later rise to the rank of brigadier general. Doriot envisioned an "Institute of Man," a scientific laboratory that would measure the effects of the battlefield environment upon soldiers. The belief driving his vision was that the limitations placed upon human capabilities by the battlefield had to be determined if the most efficient food, clothing, and equipment were to be designed. By understanding the stresses that soldiers faced, scientists would be able to develop strategies to counteract them.

With this philosophy serving as a beacon, improvements came rapidly. Climatic chambers in Lawrence, Massachusetts, were put to wartime use for studying and testing clothing and equipment in hot and cold environments. These studies, complemented by others conducted at the Quartermaster Center at Ft. Lee, Virginia, generated basic fabric-performance criteria for the design of new and improved material. Similarly, work done at the Climatic Research Laboratory in Jeffersonville, Indiana, resulted in advances in mildew-resistant finishes for tent fabrics. Meanwhile, at the Subsistence Research Laboratory in Chicago, scientists developed field-feeding systems that enabled a variety of new foods to be quickly produced and shipped to troops around the world.

The strides that had been made in research and development during World War II convinced the army of the need for a continuing program devoted to protecting and sustaining soldiers. Just as clear, however, was the need for consolidating the scattered elements of the Quartermaster Research and Development Branch. A campaign was launched to establish a single modern laboratory dedicated to the study of human beings and their environment—the realization of Doriot's Institute of Man.

In 1947 legislation was introduced in Congress to create such a facility in the Boston area. New England was the favored location from the beginning, boasting not only some of the most renowned educational centers in the country but also the wide climatic variation that would aid in the kind of experiments that the laboratory would be conducting. Other parts of the country did not view the issue as plainly, however, and waged a pitched battle in congressional hearings for the privilege of being the host of the new facility. Eventually Congress agreed to turn the matter of site selection over to the Department of Defense, which after reviewing some 278 proposals from 40 states, finally announced its choice of Natick in 1951. Three years later the facility was dedicated as the Quartermaster Research and Development Center.

The name of the facility has changed several times over the years, as has the army command under which it serves.

U.S. Army SSCOM Photo

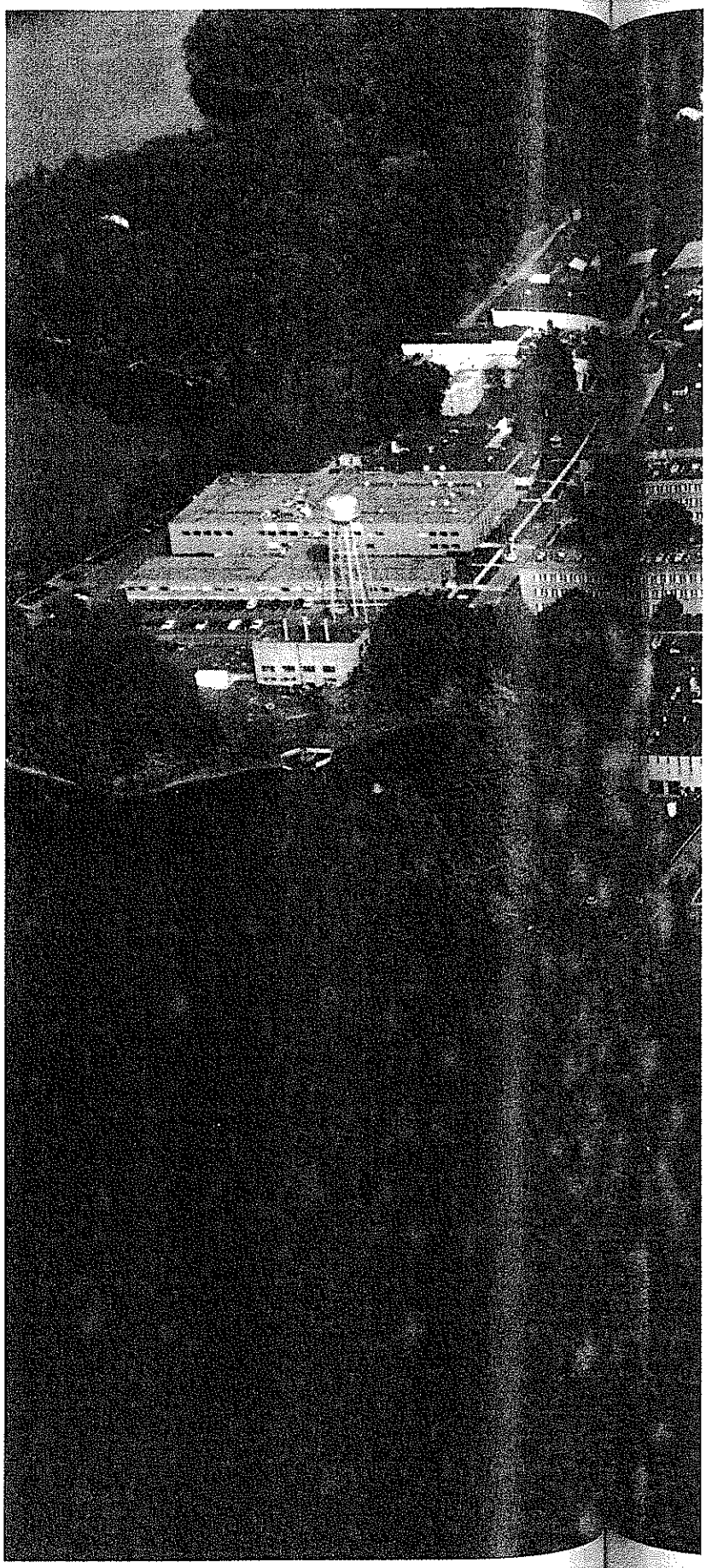
Col. Georges Doriot established the philosophy of the Natick Labs with his vision of a scientific institute that would study the effects of the battlefield environment on soldiers.

Today the Natick Research, Development and Engineering Center serves as a subordinate activity of the U.S. Army Soldier Systems Command (SSCOM), which is also headquartered in Natick. Together these agencies pursue a concept of the 21st-century military that sees the soldier as a system and that integrates all the elements that support the soldier into a single package to enhance performance and improve the quality of life.

ORGANIZATION AND FACILITIES

Known locally by its most enduring name, the Natick Labs, the center is situated on a peninsula overlooking Lake Cochituate, a fertile body of water divided into three basins stretched across almost 250 hectares (more than 600 acres) and connected by navigable culverts. Much of the shoreline has been preserved as a state park, which gives the area around the Natick Labs a pristine, natural feeling. Although the lake originally provided the center with water for cooling purposes, today it serves only as a picturesque backdrop for visitors, employees, and military families.

The town of Natick is a residential community located 24 kilometers (15 miles) south-



A wooded peninsula on Massachusetts's Lake Cochituate is home to the Natick Labs. The shoreline also supports a state park, which gives the site a rural atmosphere.

U.S. Army SSCOM Photo

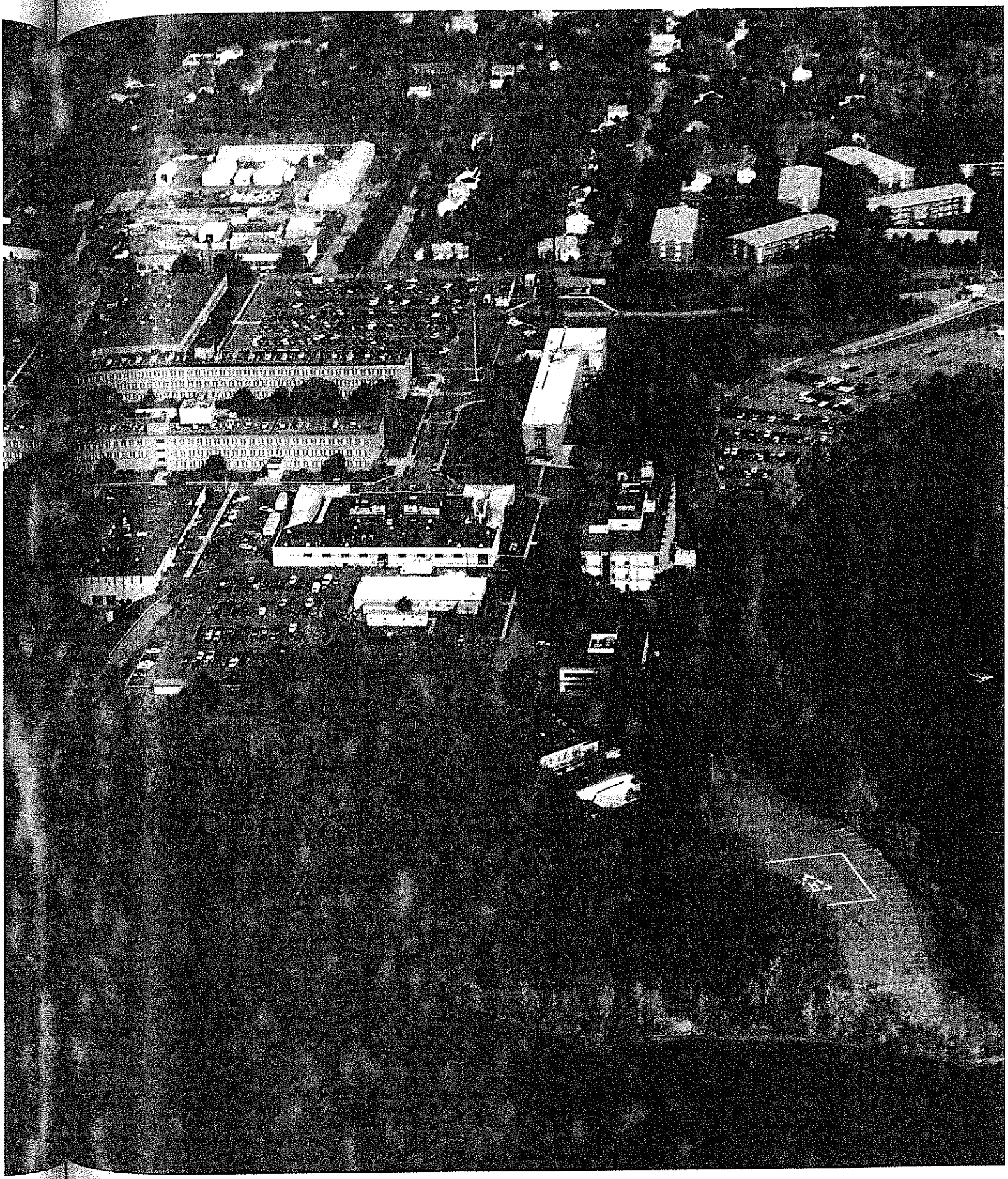
west of Boston, mixing an older downtown area with modern suburban architecture and Victorian-era mansions hidden on quiet, leafy streets. The Natick Labs participates in the life of the community in a number of ways. For example, school groups and interested citizens are regularly invited to the post to tour the facilities, and Natick researchers travel to local schools to perform classroom demonstrations aimed at increasing students' interest in science.

With its colorful foliage and 1950s-era design, SSCOM's campus has the look of a small college. The post comprises 36 buildings, although much of the work of the Natick Labs is done in the two most prominent, the appropriately named Research and Development buildings. Another large building, affectionately dubbed the Blue Palace, houses the kitchen facilities used for research into ration design.

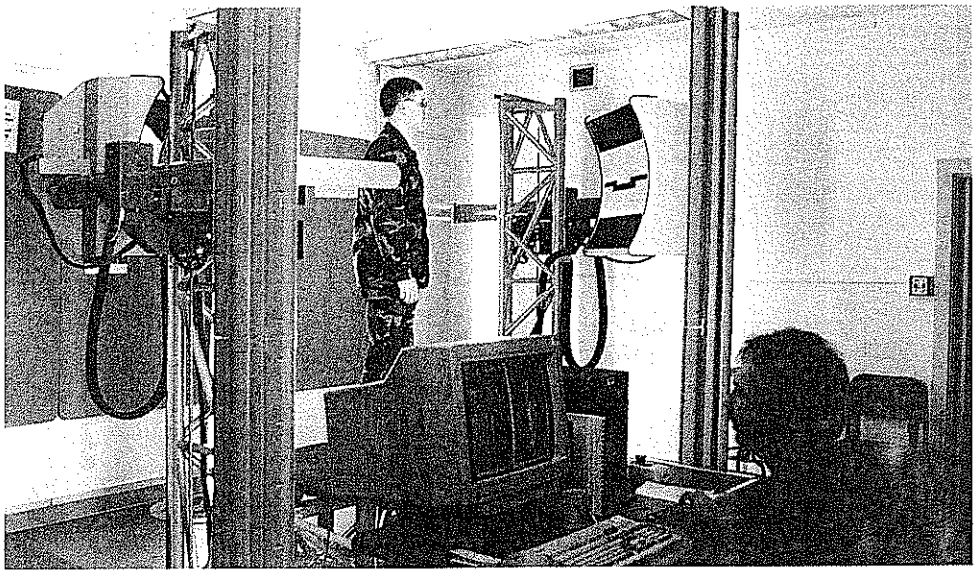
Natick employs about 500 people, mostly civilians, and is divided into four research groups. The Mobility Directorate is charged with developing airdrop systems, including personnel and cargo parachutes. The Science and Technology Directorate investigates human behavior and performance and explores new materials and textiles. The task of developing rations, shelters, field kitchens, and other equipment for use in the field, including showers and latrines, falls to the Sustainability Directorate. Finally, the Survivability Directorate develops protective clothing, helmets, boots, and other personal equipment for soldiers.

Natick has several exceptional design and testing facilities that support the directorates in their research. In the Camouflage Evaluation Facility, scientists and engineers test and evaluate new camouflage patterns in four environmental settings: woodland, desert, urban, and arctic. Because the lighting in the facility can be adjusted to simulate various day and night conditions, including different levels of moonlit and moonless night skies, evaluators have a realistic and reliable tool for measuring the performance of new and non-U.S. camouflage materials under a variety of conditions. The facility is complemented by a digital Terrain Analysis System, which breaks down videotaped footage of real environments into a user-specified number of predominant colors and shapes. The natural patterns that the system extracts from a given environment can then be used to design new camouflage patterns.

Natick also has a laser-based body-scanning and digitizing



Photographs, U.S. Army SSCOM



A soldier is scanned in Natick's Whole Body Digitizer (above) to collect data that will be used to optimize the design and sizing of clothing and equipment. (Right) Soldiers and their equipment undergo testing in the center's Doriot Climatic Chambers, which can simulate climatic extremes ranging from a tropical monsoon to a polar deep freeze.

system to pursue its research into three-dimensional anthropometry, the study of the geometry of the human form and its differences among populations. Both military and private industry often use anthropometric data to assess the range of body sizes within populations of interest. At Natick the scanning and digitizing system, which measures and records a body's 3-D surface coordinates, is used to optimize the design and sizing of uniforms and equipment. For instance, researchers recently surveyed the surface coordinates of the heads and faces of about 90 male and female soldiers in order to get the best possible fit from chemical protective masks.

By incorporating 3-D digital models of the human form into computer-aided design software, Natick researchers can design and evaluate clothing and equipment prior to creating actual physical prototypes. This improved understanding of human shape differences makes it possible for better-fitting clothing to be developed for the army's diverse population. Over the long term, whole-body modeling of individuals could lead to custom apparel design, commonly referred to as "apparel on demand" or "mass-produced custom." In other words, if an accurate image of an individual's surface coordinates existed, clothing then could be designed and fabricated specifically for that individual. Such technology could form the basis of a manufacturing system having great potential value to both the military and private industry.

Perhaps Natick's most essential facility is the Doriot Climatic Chambers, where soldiers test themselves and their equipment against worldwide climate extremes. The facility houses two wind tunnels, each 18.3 meters long, 3.4 meters high, and 4.6 meters wide (60×11×15 feet). Temperatures inside the tropic tunnel range from −18° to 74° C (0° to 165° F); inside the arctic tunnel the temperature range is −57° to 49° C (−70° to 120° F). With an ability to simulate rainfall at rates up to 10 centimeters (four inches) an hour and winds up to 65 kilometers (40 miles) per hour, the chambers provide valuable insight into how new items will perform in just about any environment. They also generate information on human performance relative to acclimation, dehydration, and work rates—information that has provided critical field guidance to U.S. commanders in the Persian Gulf and Somalia. The work done in the chambers is at the heart of Natick's mission, for it helps to ensure that soldiers will be fully protected, sustained, and effective wherever they are called into action.

FROM LAB BENCHES TO BATTLEFIELDS

Through programs devoted to the pursuit of basic science, Natick has often been able to nurture technologies from infancy to maturation. In a recent, ongoing example of that process, the center's scientists have employed a technique called electrospinning to produce an experimental new fabric that could one day be used to make seamless garments. Electrospinning is a process by which a polymer solution is charged to high voltage. At a certain voltage level a fine jet shoots out from the solution and travels through air toward

an electrically grounded target, forming a continuous polymer fiber made of numerous filaments. As it reaches its target, the fiber splays into its component filaments and dries, which results in a web of fine, interconnected filaments—*i.e.*, a nonwoven fabric.

Electrospinning gives scientists the ability to bring together a variety of polymer types and fiber forms into a single material and to produce ultrathin membranes. Microporous thin membranes are used in protective garments, sport clothing, and even diapers, and they offer significant advantages in weight reduction, comfort, and protection against toxic substances. Depending on the specific polymer used, fabric properties such as strength, weight, and porosity could be customized in the resulting electrospun textile. Natick scientists hope to incorporate into one fabric desired values of such diverse properties as electrical conductivity, chemical reactivity, flammability, and resistance to wind and water. Ultimately they would like to be able to electrospin fibers directly onto 3-D garment forms obtained through whole-body scanning and modeling. Made with the help of computer-aided design and manufacturing processes, the resulting garments would be not only custom-fit but also seamless, which would reduce a soldier's risk of chemical exposure during battle.

In another instance of cutting-edge basic science, Natick researchers are helping to realize a longtime goal of fiber-industry specialists: the duplication of spider silk for potential use in ballistic protective clothing. The fiber used in such clothing must be high in strength, in modulus (a mathematical term that in this case refers to a fiber's stiffness), and in extensibility (the amount it can elongate under tension before breaking). In other words, it must be very tough. Currently the army's protective vests and helmets incorporate fibers of Kevlar, the trademarked name of an aramid polymer made by Du Pont. Although Kevlar fibers are tough, spider silk is three times tougher. A major reason for spider silk's preeminence lies in its superior extensibility. Consequently, it can absorb more mechanical energy without breaking and, theoretically, stop a projectile more effectively. The superior qualities of spider silk also make it a highly attractive material for such applications as parachute cords, fiber-composite materials, and surgical sutures.

In a major breakthrough in the long struggle to duplicate spider silk, Natick researchers have successfully cloned the gene that codes for the protein constituting the dragline silk of the golden orb weaver spider (*Nephila clavipes*). In addition, they have made synthetic genes, based on the natural gene, whose protein products mimic spider dragline silk. By means of recombinant DNA technology, both natural and synthetic genes have been inserted into *Escherichia coli* bacteria, which in turn have been induced to produce small quantities of silks in a fermenter. Fibers have been spun from the bacterially produced silks, and several patent applications on the technology are in the works.

Scientists still must overcome many challenges before the worth of spider silk as a ballistic protective material can be proved. Perhaps most significant is the need to ascertain how the recombinant bacteria can be coaxed into producing larger quantities of the silk. Spider silk protein has proved to be uncommonly difficult to work with, both for humans and for the normally prolific *E. coli*.

U.S. Army SSCOM Photo

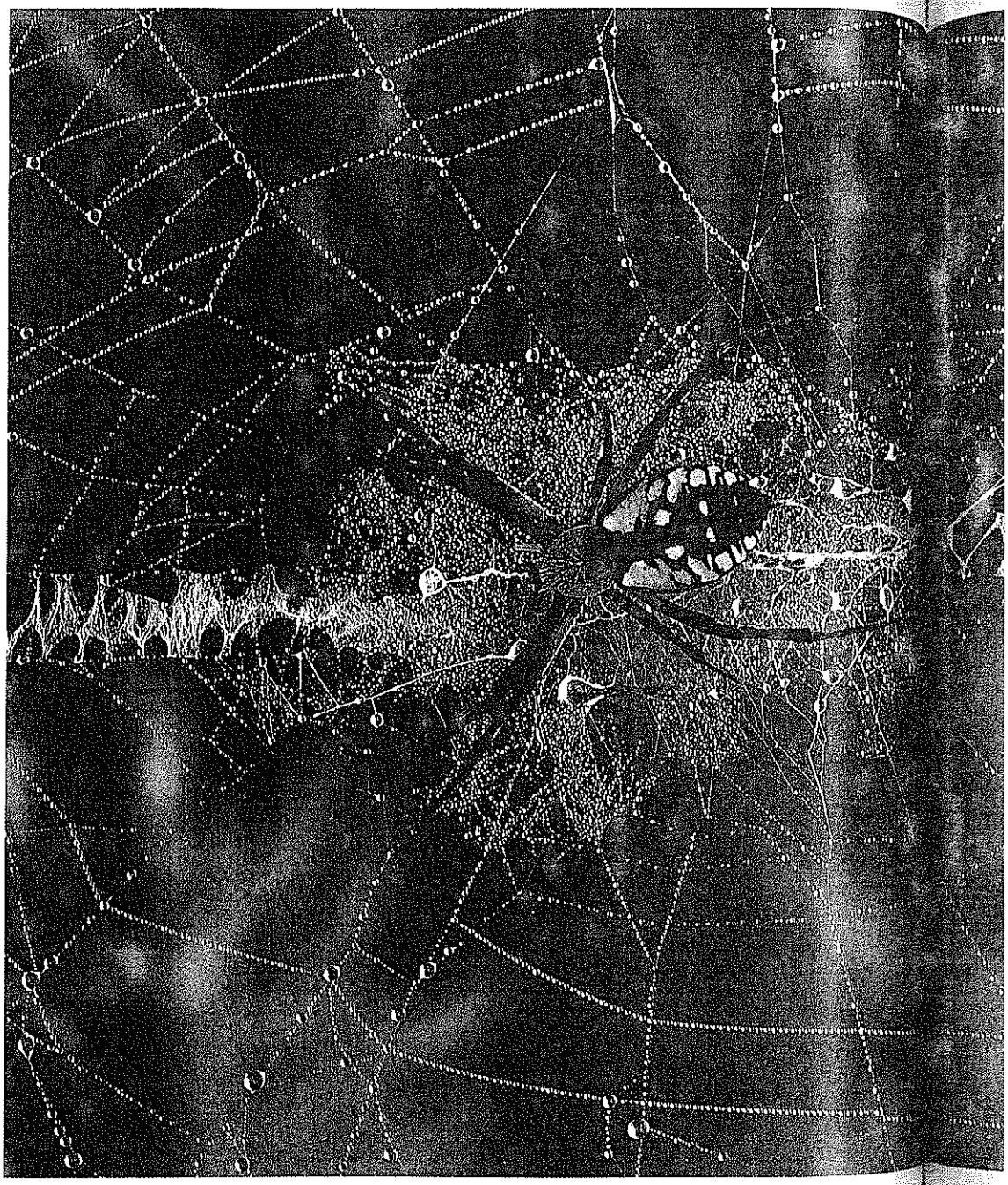
This nonwoven polymer membrane is a product of electrospinning, a technology being developed by Natick scientists. Electrospinning offers the ability to create ultrathin protective fabrics having customized properties.

LIFESAVING CLOTHING

Natick's world leadership in providing superior protective clothing is especially notable in the area of ballistics. The center's engineers have to develop gear that meets the twin challenges of protecting the soldier as thoroughly as possible from shrapnel and bullets while being light enough to avoid unduly restricting the soldier's mobility. Currently researchers are developing a new ballistic protective vest, the Modular Body Armor system, as a lighter-weight replacement for the army's present body armor. Its weight reduction will not only increase a soldier's mobility and survivability but also reduce the likelihood of heat stress.

Modular Body Armor combines two ballistic protection features. It has a "soft" component, the vest itself, that protects against fragmentation—shrapnel and other explosive

Natick scientists have cloned the gene for the dragline silk protein of the golden orb weaver spider (right) and have inserted it into bacteria, which then have been induced to make small amounts of silk in a fermenter (bottom right). The broken end of a silk strand (bottom left) has been magnified thousands of times for studies of silk's toughness.



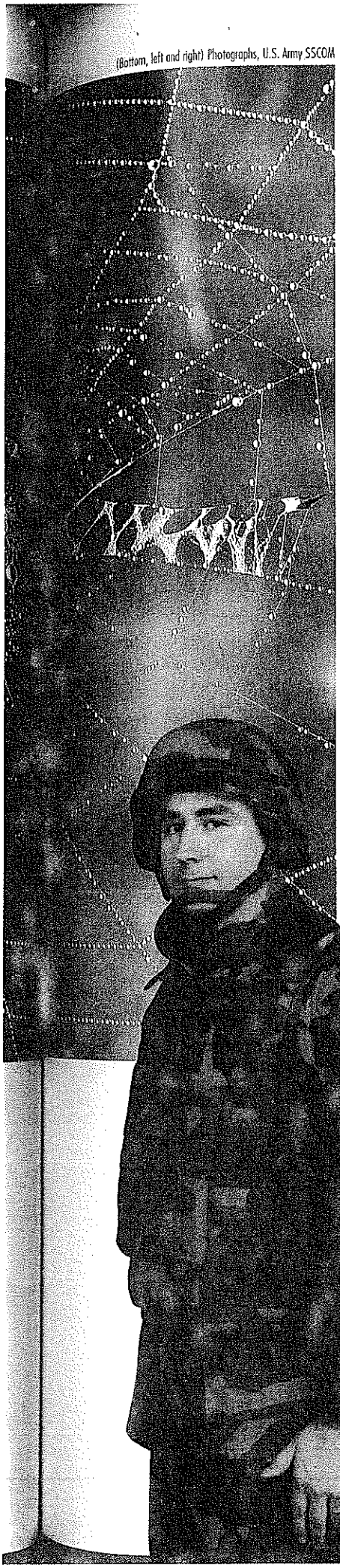
debris—and handgun bullets. The army's current vest is made of 13 layers of a particular Kevlar weave. The materials under investigation for the new vest include a variety of other weaves of Kevlar and additional high-performance fibers such as ultrahigh-molecular-weight polyethylene, liquid-crystal polymers, and other aramid-based fibers.

Modular Body Armor also has a "hard" component, a set of removable plates inserted into front and back pockets on the vest, for protection against rifle bullets. The hard plates currently designated for the system are made of a ceramic material, although researchers are investigating the performance of metal plates, primarily titanium, as well. The plates are backed up by a fiber-reinforced composite with a plasticized resin that supports the ceramic against the force of a ballistic impact.

With chemical and biological weapons—toxic chemical agents and infectious microbes, respectively—posing a particularly ominous battlefield threat, work is also under way to develop comprehensive protection for soldiers against those less-traditional forms of warfare. Two areas of research are being pursued. The Joint Service Lightweight Integrated Suit Technology (JSLIST) pro-

(Top) Stephen Krasemann—Tony Stone Images; (above, left and right) Photographs, U.S. Army SSCOM

(Bottom, left and right) Photographs, U.S. Army SSCOM



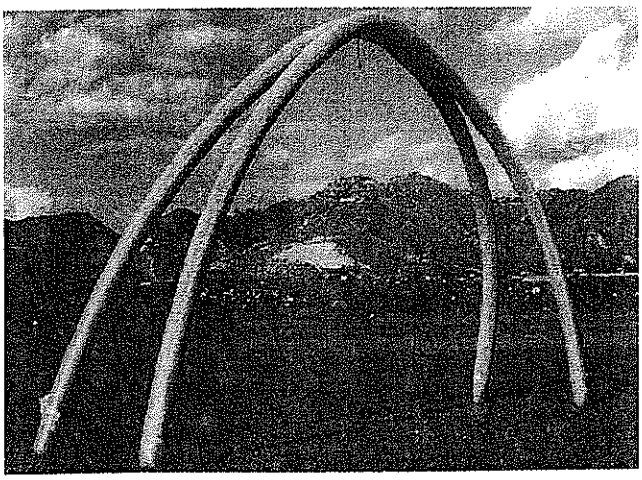
gram, based at Natick, is a consolidated effort of the four major branches of the U.S. military to design and develop the next generation of protective garments based on materials that are permeable to air and water vapor yet effectively block chemical and biological agents.

Such materials employ two layers of fabric. The outer layer has all the typical attributes of good environmental protection, including water resistance, low flammability, and the ability to be imprinted with a camouflage pattern. The inner layer contains activated carbon that adsorbs the toxin and prevents it from getting through to the skin. If the toxin is delivered as a liquid rather than a vapor, the water-repellent outershell fabric causes the liquid to bead on the surface and evaporate without penetration. Since the layers pass air and water vapor, body sweat can evaporate and leave, which vastly minimizes the risk of heat stress among soldiers wearing protective clothing in warm climates.

The JSLIST program has already developed an overgarment that reduces the weight and bulk associated with protective clothing, is launderable, and is durable enough for 45 days of wear. It also has an integrated hood and thus offers improved protection where the soldier's mask meets the garment. The accompanying boot is durable enough for 60 days of wear and is fire-retardant and petroleum-, oil-, and lubricant-resistant.

The second avenue of research pursued by Natick scientists involves clothing that incorporates a so-called permselective barrier, which would be particularly effective against biological agents and would reduce weight even more. The fabric of the garment would still consist of two layers, but the inner layer, made of a polymeric film, would be much thinner and lighter than the activated-carbon–based fabrics. The film would act as a diffusion barrier with selective permeability; it would be impermeable to air and would retard the penetration of organic chemical toxins, but it would permit sweat to evaporate and leave. This inner layer would offer protection not only against liquid and vapor chemical toxins but also against aerosols, the primary method of delivering biological agents. Since permeation rates of organic compounds differ from

Modular Body Armor (left) combines a "soft" vest made of Kevlar and other high-performance fibers with "hard" ceramic or metal plates that slip into front and back pockets on the vest. (Below) Designed for tent support, these inflatable fabric arches, or airbeams, are made by means of a new seamless three-dimensional weaving and braiding technology developed at Natick.



one permselective barrier to another, it is the ability to predict the properties of these barriers that lies at the cutting edge of research in the field.

NEW TEXTILE TECHNOLOGY

One of the more significant avenues of research being pursued by Natick's experts in soft-shelter systems is a textile technology that promises new levels of mobility and protection to soldiers in the field as well as broad applications in areas beyond the world of tents. Natick has developed techniques for weaving and braiding fabrics in three dimensions to make seamless fabric tubes. When inflated under high pressure, the tubes can function as arches, or airbeams, in place of metal frames for tent structural support. Airbeams allow for rapid, easy deployment and for tents that are significantly lighter than traditional shelters.

The high-strength structural fabric tube produced by the new technology is unlike that used to make commercial inflatable shelters. Most commercial inflatables are seamed—conventional flat-manufactured fabrics are coated, cut into patterns, and then glued or heat-welded together. Application of this technique to military shelters has shown that air inevitably leaks out through the seams, which reduces the pressure and the strength of the inflatable. The new seamless 3-D weaving and braiding techniques result in high-strength structures with improved reliability and durability.

The U.S. Navy is interested in extending the technology beyond airbeams to build lightweight, high-strength water and fuel-transfer containers and ejection-seat stabilizers for aircraft. Seamless fabric tubes could serve a variety of other military and civilian needs as well—for example, in constructing dams and other flood-control devices, safer breakwaters for offshore bases, ammunition barricades, inflatable space antennas, pollution-control devices, humanitarian-relief shelters, inflatable boats, and aircraft escape slides.

(left) AP/Wide World; (right) U.S. Army SSCOM Photo

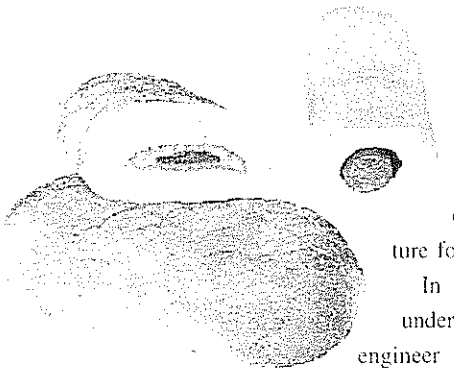
Hot pasta and chicken entrees (above) are among the menu choices for the shelf-stable Meal, Ready-to-Eat (MRE) field ration. A soldier (right) activates a chemical ration heater with water to warm his MRE.

THE ARMY'S KITCHEN

State-of-the-art food facilities have solidified Natick's standing as the army's kitchen. In fact, all of the recipes used by the U.S. armed forces in military dining facilities around the world are tested in kitchens located in the Natick Labs. New recipes are developed and tested according to new findings in nutrition, new trends in taste, and the changing dietary needs of the religiously and ethnically diverse military population. All army field rations are also tested on the premises, as are commercial products that may one day be included in those rations.

Its extensive food-testing, processing, and packaging capabilities have allowed Natick to take the lead in innovative ration design. It was a pioneer in the development of freeze-dehydrated foods, and it developed early cake mixes during World War II. In the 1960s it was also a leader in perfecting high-altitude feeding systems like Tube Foods, which are semisolid entrees and desserts contained in aluminum containers that resemble toothpaste tubes. Originally used by astro-

Natick's Mobility Enhancing Ration Components (MERC) system includes peanut-butter-and-jelly (right) and sausage (far right) pocket sandwiches. MERCs are eat-on-the-run convenience foods that require no heating or special storage.



nauts in the Mercury, Gemini, and Apollo programs. Tube Foods are now designed for pilots who fly at high altitudes and must eat while wearing oxygen masks. More recently, Natick was the birthplace of the Meal, Ready-to-Eat (MRE), the standard army field ration that has been served to soldiers since 1980, when it began replacing the Meal, Combat Individual, or C ration. More than 100 million of these meals were sent to troops in Saudi Arabia during the Persian Gulf War in 1990–91.

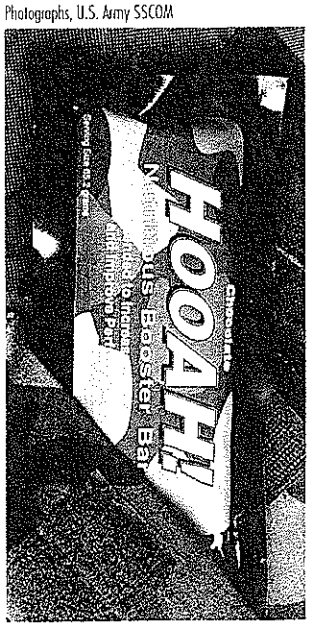
The groundbreaking MRE, which meets the calorie- and protein-intensive standards of the military's recommended-daily-allowance guidelines set by the U.S. surgeon general, is designed for long-lasting freshness. Owing to a triple-laminate foil packaging technique that protects the food from oxygen and moisture, two primary culprits in spoilage, MREs are shelf-stable for a minimum of three years at 27° C (80° F) and a minimum of six months at 38° C (100° F). The packaging process, which incorporates heat pasteurization, oxygen scavengers that absorb excess oxygen, and vacuum seals that keep out food spoilants, makes the use of chemical preservatives unnecessary.

Soldiers heat their MREs in the field, using "flameless ration heaters," which the Natick Labs developed so that troops in remote locations could enjoy hot food. Pouring a small amount of water in the polyethylene bag containing the heating mixture—a blend of food-grade magnesium, iron, and salt—triggers a chemical reaction that causes the water to boil. Simply by adding water to the heating bag and dropping in an entree pouch, a hungry soldier can have a fully heated meal in 10 minutes' time.

Natick continues to make new advances in ration design. One is the development of Mobility Enhancing Ration Components (MERCs), a flexible ration system that gives soldiers all the eat-on-the-run convenience of sandwiches. MERCs are nutritious shelf-stable pocket sandwiches—barbecued chicken, salami, and peanut butter and jelly are among current offerings—that require no heating, stay fresh in storage, and are suitable for all climates. They represent a breakthrough in the state-of-the-art technology of intermediate moisture foods.

In addition, efforts are under way to develop and engineer foods that will enhance the physical and mental performance of combat soldiers during extended operations and under all climatic conditions. Referred to as Performance Enhancing Ration Components (PERCs), these foods will be formulated with a balance of ingredients that have a proven potential to enhance performance. Incorporating complex carbohydrates, caffeine, glutamine, tyrosine, and choline as possible enhancements, PERCs will be designed to provide extra energy, delay fatigue, improve response time and decision making, and minimize declines in performance under stress. Products developed to date include a high-energy food bar called the HooAH! Bar and a beverage called the ERGO (Energy Rich, Glucose Optimized) Drink that acts as a source of supplemental carbohydrates. Both products will be issued to soldiers in the near future.

Photographs, U.S. Army SSCOM

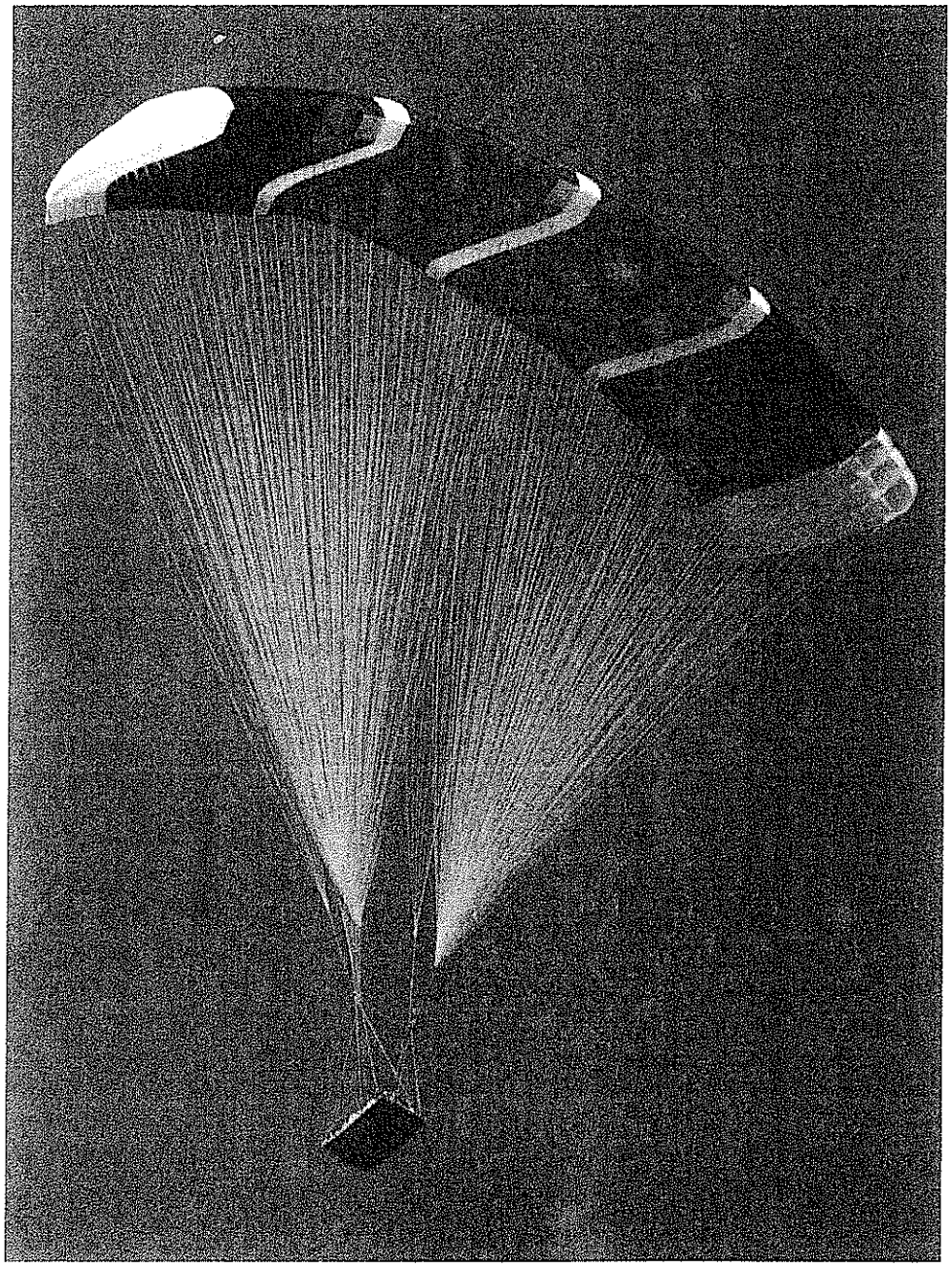


The HooAH! Bar is one of a line of Performance Enhancing Ration Components (PERCs) developed by Natick's food experts to boost a soldier's energy and delay fatigue under stress.

COMING DOWN EASY

Parachutes have long played an important role in the deployment of soldiers and supplies, and airdrop technology will become even more vital as humanitarian operations increase in frequency and create a demand for the quick delivery of food, medicine, and relief shelters. Parachutes also have become integral to the completion of space missions, such as the landing of Mars Pathfinder on the Martian surface in 1997 and the descent of the Galileo probe into Jupiter's atmosphere in 1995. For such reasons Natick is constantly looking at ways to improve airdrop capabilities. Using the considerable

U.S. Army SSCOM Photo



Natick's Advanced Precision Aerial Delivery System uses a wing-shaped parafoil canopy and an automatic navigation system to deliver payloads from high altitudes precisely where needed.

number-crunching power of new supercomputers, the center's aerospace engineers are conducting leading-edge research that should pave the way for more efficient and better targeted parachute design and safer parachute deployment.

Understanding the aerodynamic forces that govern the deployment, inflation, terminal descent, and impact of airdrop systems is important to designing parachutes. The physics of these events are very complex, however, because they involve not only the motion of the airdrop system itself but also the turbulent and unsteady airflow around and through the parachute. Analytic or numerical models describing and predicting parachute deployment and inflation have thus been difficult to construct, and designers have traditionally relied on trial-and-error field tests to reveal the effects of the interaction of these physical forces on their creations. Natick is overcoming that limitation, developing analytic computer models that accurately predict the physics of parachutes.

The aerodynamic forces influencing parachute inflation are characterized by the interaction between fluid dynamics—that is, the velocity and pressure distribution caused by the airflow in and around the parachute's canopy—and structural dynamics, which involves the solid parts of the airdrop system, including the fabric of the canopy, the suspension lines, and the payload. This interaction makes it impossible to predict the pressure distribution on a canopy surface without an accurate representation of the canopy's shape. At the same time, however, the shape of the canopy cannot be described without an accurate representation of the pressure distribution on the surface.

Along with colleagues across the country, Natick researchers are attempting to numerically integrate software that predicts fluid dynamics with software that predicts structural dynamics. They have developed a two-dimensional model for an airdrop system featuring this integration and are working with researchers at the University of Connecticut to apply the approach in three dimensions. Advances in high-performance computing are making such intricate simulations possible. Researchers hope that one day they will be able to offer engineers a rela-

tively user-friendly design tool that will predict parachute performance ahead of field testing.

THE SOLDIER AS FIGHTING SYSTEM

On the battlefield of the future, as threats become more sophisticated, soldiers will have computer technology at their fingertips, even incorporated into their uniforms. Clothing and equipment design, therefore, is entering a renaissance, and opportunities abound for advances in soldier protection and comfort. Natick's researchers are investigating so-called smart textiles, fabrics with built-in sensors that can identify and adapt to various threats. The center is also taking a leading role in developing protective countermeasures to threats from directed-energy weapons, such as lasers, which produce beams of concentrated energy. Eye protection in the form of a device that guards against tunable lasers is at the center of present research, but there will be a greater need for directed-energy protection if weapons capable of projecting destructive levels of microwave energy become a significant part of the battlefield.

The project that stands at the forefront of these efforts, weaving together the strands of all of Natick's research, is

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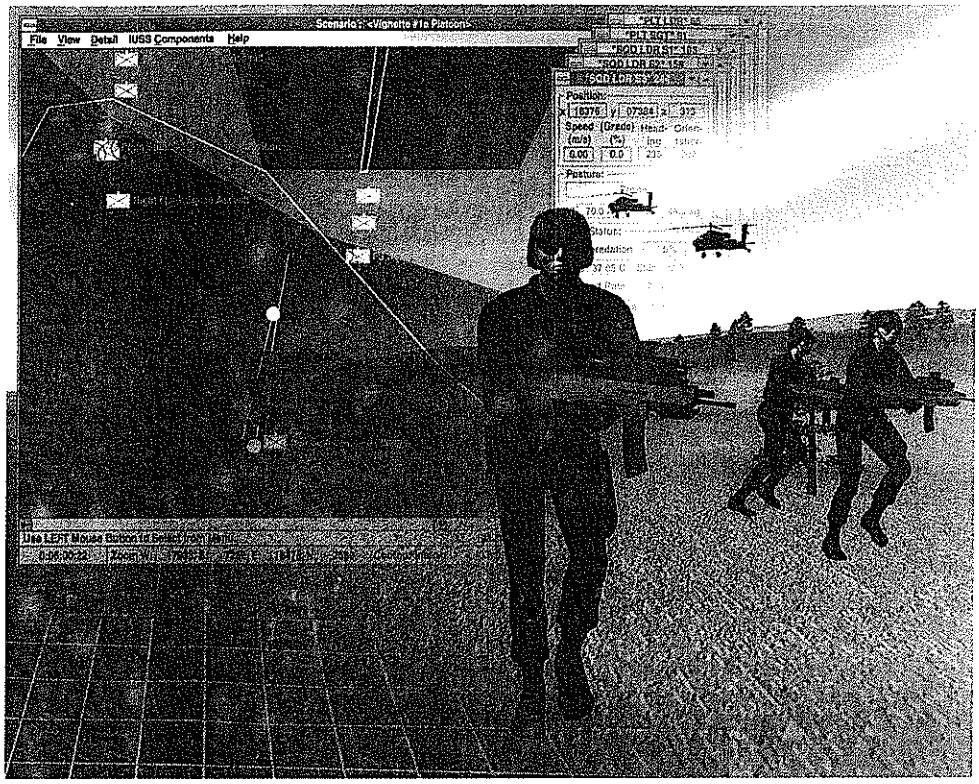
On the digitized battlefield of the future, soldiers will have computer technology incorporated into their uniforms and equipment. Each soldier will be a complete weapons platform whose equipment is united by design into a single, performance-optimized system.



Land Warrior, a revolutionary program to develop a totally integrated soldier fighting system for the 21st century. The concept behind Land Warrior is the view of the soldier as a complete weapons platform—the soldier whose individual equipment is united by design into a single, performance-optimized system. One of the most striking elements of the system is its helmet, which has a mounted computer and sensor display that acts as the soldier's interface to the other components of the system and to the battlefield. Through the display, the soldier can view computer-generated graphic data, digital maps, intelligence information, troop locations, and imagery from a heat-sensing Thermal Weapon Sight and video camera on the soldier's weapon. The weapon-mounted imaging devices allow a soldier to aim and fire at a target around a corner without exposing more than hands and arms.

As the concept of the soldier changes, as the individual's role on the battlefield becomes more complex, Natick's research becomes at once more sophisticated and more humble, focused, as always, on an understanding of the soldier as a human being. By continuing to support and sustain soldiers in comfort, by placing a premium on their nutritional needs, and by designing equipment to keep them safe, Natick will be able to shape a 21st-century military force that is technologically driven but people-centered.

INTERNET RESOURCE

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